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Framework for Building Categories and Benchmarking Approach

Overview

The BEARS rating will be determined by comparing a rated building to an energy benchmark. Due to the diverse nature of building types and their energy performance, benchmarks will be derived based on building categories. This document summarizes the process to define the building categories used for the BEARS system and the approach used to derive the benchmarks for each building type.

Defining BEARS Building Types

Several existing building rating or database frameworks have been reviewed to compare building and occupancy type categories for their potential use as the BEARS framework. These include the California Commercial End Use Survey (CEUS), U.S. Commercial Building Energy Consumption Survey (CBECS), DOE Commercial Reference buildings, and The Chartered Institution of Building Services Engineers (CIBSE) 2008 Energy Benchmarking (TM46) used in the United Kingdom. A summary of each building category framework is provided below.

Commercial Buildings Energy Consumption Survey (CBECS): The 2003 version of the CBECS dataset contains 5,215 buildings, and separates the commercial sector into 14 general types, 29 categories, and 51 subcategories based on principal building activity. Buildings used for more than one activity are assigned to the activity occupying the most floor space. In the 1999 and 2003 CBECS, respondents were asked to place their building into a sub-category that was a more specific activity than has been collected in prior surveys.

California Commercial End-Use Survey (CEUS): The California Commercial End-Use Survey is a sample of 2,790 commercial facilities and was collected from the service areas of Pacific Gas and Electric, San Diego Gas & Electric, Southern California Edison, Southern California Gas Company, and the Sacramento Municipal Utility District. The sample was stratified by utility service area, climate region, building type, and energy consumption level. Twelve distinct commercial building types were identified for classification based on Standard Industrial Classification (SIC) codes.

DOE Commercial Prototype / Reference Buildings: The U.S. Department of Energy (DOE) developed commercial reference buildings for use in energy modeling software research by providing complete descriptions for whole building energy analysis using the EnergyPlus simulation software. There are 16 building types that represent nearly 70% of the commercial buildings in the U.S. These modules provide a consistent baseline of comparison and improve the value of computer energy simulations using software such as EnergyPlus. Commercial reference building models are available for new construction, existing buildings constructed in or after 1980 ("post-1980"), and existing buildings constructed before 1980 ("pre-1980"). From the Commercial Reference Buildings, DOE has also developed Prototype Models, which provide buildings that are compliant with ASHRAE 90.1-2004, 90.1-2007 and 90.1-2010. The Prototype models cover the same buildings as the Reference models, except that supermarket has been replaced by hi-rise apartment.

(CIBSE) 2008 Energy Benchmarking (TM46): CIBSE developed benchmarks to complement the Operational Rating procedure developed by the Department for Communities and Local Government (CLG) for Display Energy Certificates. Display Energy Certificates are required in the United Kingdom for buildings with a total useful floor area greater than 1000 m^2 that are occupied by a public authority or an institution providing a public service to a large number of people. The benchmark has 29 building type categories. Mixed use buildings may be split into their component uses for separate assessment of each type of use. Otherwise, a composite benchmark based on the relative percentage of total usable floor area allocated to each use may be calculated.

A matrix of building occupancy categories for the various frameworks reviewed was developed, grouping similar types together for comparison.

Table 1: Building Category Types Comparison Matrix

CBECS Building Types	2003 CEUS Building Types	2003 CEUS Sub-Types	DOE Commercial Prototype/Reference Buildings	CIBSE TM46: 2008
Office	Small Office (<30k ft2)	Administration and management	Large Office	General office
	Large Office (>=30k ft2)	Financial/Legal	Medium Office	High street agency
		Insurance/Real Estate	Small Office	
		Data Processing/Computer Center		
		Assorted/Multi-tenant		
		Lab/R&D Facility		
		Software Development		
		Government Services		
		Other Office		
Food Service	Restaurant	Fast Food or Self Service	Quick Service Restaurant	Restaurant
		Specialty/Novelty Food Service	Full Service Restaurant	Bar, pub or licensed club
		Table Service		
		Bar/Tavern/Nightclub/Similar		
		Other Food Service		
Food Sales	Food Store	Supermarkets	Supermarket	Small food store
		Small General Grocery		Large food store
		Specialty/Ethnic Grocery		
		Convenience Store		
		Liquor Store		
		Other Food Store		
Mercantile	Retail	Department / Variety Store	Stand-alone Retail	General retail
		Retail Warehouse/Clubs	Strip Mall	Large non-food shop
		Shop in Enclosed Mall		
		Shop in Strip Mall		
		Auto Sales		
		Other Retail Store		
Health Care	Health Care	Hospital	Hospital	Clinic

		Nursing Home	Outpatient Health Care	Hospital; clinical and research
		Medical/Dental Office		Emergency services
		Clinic/Outpatient Care		
		Medical/Dental Lab		
Warehouse and Storage	Refrigerated Warehouse	Refrigerated Warehouse	Warehouse	Storage facility
	Unrefrigerated Warehouse	Unconditioned Warehouse, High Bay		Cold storage
		Unconditioned Warehouse, Low Bay		
		Conditioned Warehouse, High Bay		
		Conditioned Warehouse, Low Bay		
Lodging	Lodging	Hotel	Small Hotel	Hotel
		Motel	Large Hotel	Long term residential
		Resort		General accommodation
		Other Lodging		
Education	School	Daycare or Preschool	Primary School	Schools, seasonal public bldgs
	College	Elementary School	Secondary School	University campus
		Middle / Secondary School		
		College or University		
		Vocational or Trade School		
Public Assembly	Public Assembly	Religious Assembly (worship only)		Cultural activities
Public Order and Safety		Religious Assembly (mixed use)		Entertainment halls
Religious Worship		Health/Fitness Center		Swimming pool centre
		Movie Theaters		Fitness and health centre
		Theater / Performing Arts		Dry sports and leisure facility
		Library / Museum		Public buildings with light usage
		Conference/Convention Center		Laboratory or operating theatre
		Community Center		Public waiting or circulation
		Other Recreational/Public Assembly		
Service	Services	Gas Station / Auto Repair		Terminal
		Gas Station With Convenience Store		Workshop
		Repair (Non-Auto)		Covered car park
		Other Service Shop		
	Miscellaneous	Assembly / Light Mfg.		
		Police / Fire Stations		
		Post Office		
Other	Other	Other Unlisted Type		
Vacant				

Under all of these frameworks, buildings are classified according to the principal activity of the building, with buildings having multiple activities either assigned to the activity occupying the most floor space, or split for separate assessment of each usage type. Although there are other categorizing methods (e.g., building size, construction attributes, HVAC system type) because energy use is more contingent on principal activity than any other characterization, it is recommended that BEARS utilize principal activity (occupancy category) as the primary framework for classification.

As BEARS will be utilizing a modeling approach to benchmarking, utilizing the DOE Commercial Reference Buildings/Prototype models framework for building category types to leverage the models developed for 16 building types would be a sensible approach. These reference building types were developed through analysis of CBECS data to discern the most typical building types and attributes. The 16 building types represent nearly 70% of the commercial buildings in the U.S. Utilizing the Commercial Reference/Prototype Buildings as a foundation for the BEARS framework would allow for leveraging years of DOE's research, modeling, benchmarking, and validation of the modeling and operational parameters of each building type.

Development of several additional model types beyond the Commercial Reference/Prototype Buildings to encompass further building types in the BEARS rating may be explored. To consider additional types, the 2003 CEUS Building Sub-types were evaluated to assess which may have significantly different energy consumption and modeling parameters from the DOE Commercial Reference Buildings. These additional types are identified in the third column of the following table.

Table 2: Additional Building Types for Consideration Beyond DOE Commercial Reference Buildings

2003 CEUS Building Types	DOE Commercial Prototype/Reference Buildings	Additional CEUS Types/Sub-Types for Consideration Beyond DOE Commercial Reference Buildings
Small Office (<30k ft2) Large Office (>=30k ft2)	Large Office Medium Office Small Office	Data Processing/Computer Center Lab/R&D Facility
Restaurant	Quick Service Restaurant Full Service Restaurant	Bar/Tavern/Nightclub/Similar
Food Store	Supermarket	Convenience Store
Retail	Stand-alone Retail Strip Mall	
Health Care	Hospital Outpatient Health Care	
Refrigerated Warehouse Unrefrigerated Warehouse	Warehouse	Refrigerated Warehouse Unconditioned Warehouse Conditioned Warehouse
Lodging	Small Hotel Large Hotel Midrise Apartment	
School College	Primary School Secondary School	College or University
Public Assembly		Religious Assembly Health/Fitness Center

	Theater / Performing Arts Library / Museum Conference/Convention Center Other Recreational/Public Assembly
Services	Service
Miscellaneous	Assembly / Light Mfg. Police / Fire Stations

The DOE Commercial Reference Building types and the additional CEUS Sub-Types identified as having significantly different operational, energy consumption, or modeling parameters from any of the reference building types comprise a total of 31 building types for consideration in the BEARS scope. Three of these types (Hospital, Outpatient Healthcare, and Apartment) were determined to be outside of the BEARS scope. Of the remaining building types, 15 will translate directly to an available DOE Commercial Reference or Prototype Building, 6 will require modification of modeling parameters from an available Reference Building type (e.g. Warehouse, modified to represent Conditioned Warehouse, Unconditioned Warehouse, and Refrigerated Warehouse), and 10 will require substantially different modeling protocols from the Commercial Reference Buildings. Table 3 lists the recommended BEARS building types, and the modeling protocol requirements relative to the DOE Reference Buildings.

Table 3: Recommended BEARS Building Types

Recommended Bears Building Types	DOE Reference Building Available	Modify DOE Reference Building	New Models Protocols Required	Recommended for Initial BEARS Scope	Recommended for Future BEARS Scope	% of Floor Area in CEUS Database (with mapping)	CEUS Weighted Median Source EUI (kBtu/sf/yr)	Estimated Portion of Total Energy Usage
Large Office (150,000 sf and greater)	x			x				
Medium Office (25,000 – 149,999 sf)	x			x		19.42%	184.3	17.5%
Small Office (less than 25,000 sf)	x			x				
Data Processing/Computer Center		x				0.50%	610.9	1.5%
Lab/R&D Facility			x		x	0.87%	571.5	2.4%
Quick Service Restaurant	x			x		1.19%	973.6	5.7%
Full Service Restaurant	x			x		1.86%	746.9	6.8%
Bar/Tavern/Nightclub/Similar		x				0.26%	367.4	0.5%
Supermarket	x			x		2.51%	525.7	6.5%
Convenience Store		x			x	0.93%	793.3	3.6%
Stand-alone Retail	x			x		12.58%	184.0	11.3%
Strip Mall	x			x		2.85%	166.0	2.3%
Refrigerated Warehouse		x		x		1.97%	483.7	4.7%
Unconditioned Warehouse		x		x		9.45%	216.1	10.0%
Conditioned Warehouse	x			x		2.60%	228.4	2.9%
Small Hotel (up to 199,999 sf)	x			x				
Large Hotel (200,000 sf and greater)	x			x		7.74%	67.5	2.6%
Primary School	x			x		4.48%	153.3	3.4%
Secondary School	x			x		5.31%	159.3	4.1%
Hospital	x					1.86%	289.2	2.6%
Outpatient Healthcare	x					2.55%	68.5	0.9%
College or University		x				0.001%	275.9	0.0%
Religious Assembly			x		x	4.89%	63.1	1.5%
Health/Fitness Center			x			0.41%	309.5	0.6%
Theater / Performing Arts			x			0.78%	222.8	0.8%
Library / Museum			x			0.38%	173.8	0.3%
Conference/Convention Center			x			0.16%	95.4	0.1%
Other Recreational/Public Assembly			x		x	2.02%	254.2	2.5%
Service			x		x	5.90%	131.1	3.8%
Assembly / Light Mfg.			x		x	0.96%	129.3	0.6%
Police / Fire Stations			x			0.62%	183.3	0.6%

A two phase rollout of BEARS is proposed. Phase 1 will include 15 building types and future phases will include an additional 6 building types. It is also recommended that several of the identified building types be excluded from the scope of BEARS.

The goal of Phase 1 is to include the building categories that either represent a significant portion of the California building stock, or are responsible for a significant portion of California's energy consumption. Table 3 provides a summary of each building type's percentage of floor area with respect to all buildings in the CEUS database and their percentage of total energy consumption. This data was used to identify the most common building types, and the most energy intensive building types. 15 building types are recommended for initial BEARS scope, which would represent approximately 72 percent of the floor area in the CEUS database, and 78 percent of the overall energy use of the building sector. These building types are listed in Table 3, and are identified in the column "Recommended for Initial BEARS Scope."

Six additional building types are recommended for inclusion in future phases of BEARS development. These additional building types comprise approximately 15.5 percent of overall building floor area and 14.5 percent of overall energy usage with respect to the CEUS database. These building types are listed in Table 3, and are identified in the column "Recommended for Future BEARS Scope."

The building types recommended to be excluded from the BEARS rating system are those that are not identified as either "Recommended for Initial BEARS Scope" or "Recommended for Future BEARS Scope." These include:

- Building types listed above that would require significant research and development to develop completely new prototype energy models but do not account for a significant portion of floor area or energy consumption in California. These building types could be gradually added to the BEARS scope with future research.
- Data Centers – A large portion of the energy use in data centers is related to servers, which is captured by the PUE metric used by the industry. Further, HVAC systems in data centers are highly tailored to server loads, making proper benchmarking of building assets that may apply to all data centers a difficult endeavor.
- College/University – It appears that this building type was not truly represented in the CEUS database. Considering the degree of variation in size and usage for this category (classroom, recreation, student center, office, dormitory, etc.), benchmarking would prove highly difficult. This building type would be better represented by choosing a building category most similar to the actual usage of the college/university building.
- Hospital and Outpatient Healthcare – these buildings are considered institutional buildings and fall outside the scope of a commercial building asset rating program.

The CEUS database is an important resource for energy consumption data in California. In order to maintain compatibility with the CEUS building categories, further mapping of the building types was performed to correlate the 61 CEUS building sub-types to the list of 15 proposed Phase 1 building types. This recommended mapping scheme is shown in Table 4.

Table 4: Mapping of CEUS Building Types/Sub-Types to BEARS Proposed Building Types

2003 CEUS Building Types	2003 CEUS Sub-Types (Oak Ridge Data)	Mapping to Proposed BEARS Type
Small Office (<30k ft2)	Administration and management	Office (sm, md, lrg based on building size)
Large Office (>=30k ft2)	Financial/Legal	Office (sm, md, lrg based on building size)
	Insurance/Real Estate	Office (sm, md, lrg based on building size)
	Data Processing/Computer Center	N/A
	Assorted/Multi-tenant	Office (sm, md, lrg based on building size)
	Lab/R&D Facility	N/A
	Software Development	Office (sm, md, lrg based on building size)
	Government Services	Office (sm, md, lrg based on building size)
	Other Office	Office (sm, md, lrg based on building size)
Restaurant	Fast Food or Self Service	Quick Service Restaurant
	Specialty/Novelty Food Service	Quick Service Restaurant

	Table Service	Full Service Restaurant
	Bar/Tavern/Nightclub/Similar	N/A
	Other Food Service	Full Service Restaurant
Food Store	Supermarkets	Supermarket
	Small General Grocery	Supermarket
	Specialty/Ethnic Grocery	Supermarket
	Convenience Store	N/A
	Liquor Store	N/A
	Other Food Store	N/A
Retail	Department / Variety Store	Stand-alone Retail
	Retail Warehouse/Clubs	Stand-alone Retail
	Shop in Enclosed Mall	Strip Mall
	Shop in Strip Mall	Strip Mall
	Auto Sales	Stand-alone Retail
	Other Retail Store	Stand-alone Retail
Refrigerated Warehouse	Refrigerated Warehouse	Refrigerated Warehouse
Unrefrigerated Warehouse	Unconditioned Warehouse, High Bay	Unconditioned Warehouse
	Unconditioned Warehouse, Low Bay	Unconditioned Warehouse
	Conditioned Warehouse, High Bay	Conditioned Warehouse
	Conditioned Warehouse, Low Bay	Conditioned Warehouse
Lodging	Hotel	Hotel (small or large based on building area)
	Motel	Hotel (small or large based on building area)
	Resort	Hotel (small or large based on building area)
	Other Lodging	Hotel (small or large based on building area)
School	Daycare or Preschool	Primary School
College	Elementary School	Primary School
	Middle / Secondary School	Secondary School
	College or University	N/A
	Vocational or Trade School	Secondary School
Public Assembly		N/A
	Religious Assembly (worship only)	N/A
	Religious Assembly (mixed use)	N/A
	Health/Fitness Center	N/A
	Movie Theaters	N/A
	Theater / Performing Arts	N/A
	Library / Museum	N/A
	Conference/Convention Center	N/A
	Community Center	N/A
	Other Recreational/Public Assembly	N/A
Services	Gas Station / Auto Repair	N/A

	Gas Station With Convenience Store	N/A
	Repair (Non-Auto)	N/A
	Other Service Shop	N/A
Miscellaneous	Assembly / Light Mfg.	N/A
	Police / Fire Stations	N/A
	Post Office	Office (sm, md, lrg based on building size)

Defining the BEARS Benchmarks

The BEARS rating will be calculated by comparing the Rated Building's energy performance to a Benchmark Building. Two primary rating methods have been evaluated for the BEARS program: developing a building-specific energy simulation model or utilizing a performance map.

- The energy simulation model approach involves creating a model with the Rated Building's characteristics and running an annual simulation. The results of the simulation will determine the Rated Building's energy performance.
- The performance map approach relies on a database of pre-simulated models and a large number of model permutations to represent the existing building stock and new construction to the greatest extent possible. Additionally, a regression will be developed to correlate a building's characteristics with the database results. The Rated Building's energy performance will be determined by using its characteristics as inputs to the regression equations.

In both methods, the Rated Building's energy performance will be compared against a Benchmark Building. The benchmark energy use intensity (EUI) will be established for each building type and climate zone. Because operational characteristics of a building have a large impact on a building's energy use intensity, special consideration was given to their use in the determination of the asset rating.

Two approaches were considered for how the BEARS rating program could handle operational variables:

- Specify fixed values and schedules for operational variables, irrespective of the actual operating characteristics of the Rated Building. These values would be representative of a "typical" building's operation, based on the building category.
- Allow operational variables to be set to the actual operating characteristics of the Rated Building. In this scenario, operational variables are not fixed inputs and the benchmark would be adjusted up or down in response to operational variables that differ from building to building. For example, if a typical schedule for an office building was based on sixty HVAC operating hours weekly, a building with a much longer operating schedule of 100 hours per week would have its benchmark adjusted upwards to accommodate the extra hours of HVAC operation. The adjustment could follow an approach similar to ENERGY STAR, which normalizes for operational variables through regressions; alternately, adjustments could be made using simulations to directly account for variation in operating characteristics.

Altogether, four methods for calculating the BEARS rating were evaluated:

1) Energy Simulation Approach with a Static Benchmark
2) Performance Map Approach with a Static Benchmark
3) Energy Simulation Approach with a Modeled Benchmark
4) Performance Map Approach with a Modeled Benchmark

Rating Procedure using a Static Benchmark

The term *static benchmark* refers to a benchmark that outputs a constant EUI for a given building type and climate. The following steps summarize the BEARS rating procedure using a static benchmark:

- Determine the basis for establishing a benchmark target EUI for each building type and climate zone. The benchmark can be based on a building vintage (e.g. the year 2000, to leverage data from CBECS 2003) or can be tied to prescriptive code requirements. Building specific benchmark input data will be determined for each data element identified in the BEARS Field Assessment Protocol.
- Identify the operational variables and determine typical values for each. These variables include schedules, equipment loads, and occupant density and will be fixed for a given building type, regardless of the actual conditions of the Rated Building.
- EUI benchmarks would be determined by performing simulations of prototype building models with input characteristics derived from "typical data" from a given year or prescriptive code levels for each building type and climate zone. The benchmark EUI is fixed for a given building type and climate zone. It is assumed that the EUI metric will be based on time dependent valuation (TDV) energy use.
- The Rated Building's EUI may be determined by energy simulation or using a performance map as described below.
- The Rated Building's EUI would be compared to the Benchmark Building's EUI to generate a BEARS rating.

Energy Simulation Approach

The Rated Building's Energy Use intensity could be determined by developing a custom energy model representative of its assets using the following procedure:

- Specify the inputs for the model's assets as described in section 4.4, BEARS Software Specification.
- Set the model's operational characteristics identical to those used in the Benchmark Building's simulation model.
- Simulate the Rated Building, and compare it to the Benchmark EUI. The ratio of the rated building EUI to the benchmark building EUI is the asset rating as described in section 4.3, Energy Use Benchmarks and BEARS Scale.

Performance Map Approach

A second approach to determining the Rated Building's Energy Use Intensity would utilize the performance map approach:

- Perform a large set of parametric energy simulations for each building type covered in the program to populate a database with energy use intensities for a wide variety of building design characteristics.
- Develop an approach to correlate a set of building assets to the simulation results in the performance map database. Possible approaches include finding a "closest match" between the building assets and a specific database entry, or developing statistical relationships between building assets and energy use.
- For the Rated Building, the values for all building assets would be queried against the database, and the performance map would return an EUI result.
- Since the benchmark is fixed, a correlation could be developed between the building inputs and energy use, or between building inputs and the asset rating.

Rating Procedure Using a Modeled Benchmark

The *modeled benchmark* is analogous to the current performance method in the Title 24 Standards: the Rated Building features help define and constrain the Benchmark Building against which the Rated Building is compared. With this approach, the benchmark is not fixed, but unique to each rated building; there is not a single benchmark EUI for each building type/climate zone. The following steps summarize the BEARS rating procedure using a modeled benchmark:

- Determine the basis for establishing a benchmark target EUI for each building type and climate zone. The benchmark can be based on a building vintage (e.g. the year 2000, to leverage data from CBECS 2003) or can be tied to prescriptive code requirements. Building specific benchmark input data will be determined for each data element identified in the BEARS Field Assessment Protocol.
    - If the basis is a building vintage, then the Benchmark Building attributes would follow average building attributes from building databases such as CBECS or CEUS.
    - If the basis is a particular version of Title 24, then the Title 24 prescriptive requirements and the Title 24 ACM Manual define the benchmark for comparison.
- Identify operational variables, such as operating hours, schedules and equipment power density, and assign default values. For the modeled benchmark approach, these can either be fixed or neutral.
    - Fixed defaults: The Benchmark Building's operational values are set to values established in the Title 24 Nonresidential ACM, or may be derived from other data sources (CBECS, CEUS) where no code information is available.
    - Neutral defaults: The Benchmark Building's operational values are set to match the actual operational conditions of the Rated Building. For example, if the Rated Building operates for 100 hours per week, the Benchmark Building would be based on the same schedule. In this scenario, the inputs for the Benchmark and Rated Buildings track each other so that neither credit nor penalty is given for changing these values; however, they will cause the benchmark of comparison to be a non-static value.
- The Benchmark Building's EUI may be determined by energy simulation or using a performance map as described below.
- The Rated Building's EUI may be determined by energy simulation or using a performance map as described below.
- The Rated Building's EUI would be compared to the Benchmark Building's EUI to generate a BEARS rating.

Energy Simulation Approach with the Modeled Benchmark

A modeled benchmark can be used with the *energy simulation approach* to develop an asset rating. This approach provides a custom benchmark that is dependent on the rated building design, and requires two energy simulations to be run, very similar to code compliance and beyond code programs.

- Develop and apply a *ruleset* that defines how to specify model inputs for the Benchmark and Rated Buildings. Examples of existing rulesets are the Title 24 ACM, ASHRAE 90.1 Appendix G, and Savings by Design. A compliance ruleset such as Title 24 may not be adequate for asset ratings since it constrains the credit given to some technologies and building features so a BEARS Rating ruleset would need to be developed to properly assess an asset rating.
- The model inputs can follow one of the following rule classifications:
    - Prescribed (fixed). The input is a fixed value for both the Benchmark Building and the Rated Building. An example of an input that might be prescribed is the operating hours of the building.
    - Neutral. A neutral variable is one where the value in the benchmark building is set to match the value in the rated building. An example of an input that may be neutral may be the building's geometry, or its orientation. The operating hours could also be a neutral variable if it is desirable to account for actual operational schedules. As previously noted, all operational features of the building could be either prescribed or neutral using a modeled benchmark approach. This is critical decision as it will greatly influence the EUI for both the Benchmark and Rated Buildings.
    - Asset. An asset variable is one that can be used to achieve credit or penalty under the asset rating system. For example, wall U-factor or equipment cooling efficiency (COP or EER) for the Rated Building would be set to match the actual building's conditions. The Benchmark Building

would have U-factors and efficiency values that are determined from the building's vintage or from the Standards' prescriptive requirements.

Once the ruleset is determined, it may be used to calculate the building's asset rating:

- A user would develop an energy model for their Rated Building.
- The rule set would automatically generate an energy model for the Benchmark Building.
- Both buildings would be simulated using the same simulation program to determine their EUI.
- The Rated Building's EUI would be compared to the Benchmark Building's EUI to generate a BEARS rating.

Performance Map Approach with a Modeled Benchmark

When a modeled benchmark is used with a performance map approach, a rule set is developed that determines the inputs of the benchmark building as a function of the rated building. The procedure is as follows:

- A large number of parametric runs of building simulations of each building type are used to determine a relationship between building inputs and building energy use. This step is done once, and applies for the number of inputs and range of inputs in the performance map. It is vital to define all likely inputs that can be varied in the performance map to generate a rating. These variables should follow the field assessment protocol.
- Rated building inputs *that are captured by the performance map* are entered into the rating application.
- The rule set is applied to determine the corresponding value of each input for the benchmark building. As previously discussed, inputs may be prescribed, neutral, or assets. The ruleset would transform the Rated Building's inputs to define the Benchmark Building's inputs.
- Once all of the inputs are defined for the Rated Building and for the Benchmark Building, they are used to query the performance map database and retrieve EUI results for both the Rated and Benchmark Buildings.
- The Rated Building's EUI would be compared to the Benchmark Building's EUI to generate a BEARS rating.

A summary of the strengths and weaknesses of each approach is given below.

Pros and Cons of the Performance Map Approach

The performance map can be a good rating tool for buildings that are adequately captured in the performance map database. This method could potentially require less quality assurance because the user inputs would be more constrained than for those needed to develop an energy model. It may also be less costly to implement from a software development perspective because the effort would be focused on database management rather than developing sophisticated interfaces to energy simulation software.

However, a key limitation of this method is that a regression, even from a large number of simulations, might not account for some variations in the building model. The performance map cannot account for all possible design features that affect building energy use such as economizer operation, daylighting, and evaporative precooling. Even if it does account for these features, it may not account for the full range of control options that would impact performance. Therefore, this method will be unable to yield an accurate prediction of the building's energy performance if it contains features outside of the performance map's scope. Because the performance map is pre-simulated, it is less flexible in its ability to consider new/innovative design features. If this method is utilized, it is recommended that its scope be limited to small buildings (e.g., less than 20,000 ft^2) or simple buildings with more uniform and predictable characteristics (small office, small retail).

Pros and Cons of the Energy Simulation Approach

The primary advantage of this approach over the performance map is that any building feature of the Rated Building could theoretically be factored into the energy model. However it must be noted that even this approach is limited by what the BEARS system considers assets and are deemed to be affordable to collect in the field.

The primary disadvantage of this approach is increased complexity and cost, and a much greater need for quality assurance (either for the modeler, the rating software, the rating authority or a combination of these). However, a simplified interface could be developed to provide an easy means to enter building inputs determined through field data collection and plans review. The software could automatically supply other default parameters, generate building models for the rated building and benchmark building, and generate the rating. A software tool such as the Title 24 Compliance Manager being developed for the 2013 Standards could potentially be customized to perform the rating function. A disadvantage of developing a simplified interface is that it will have less flexibility than fully featured energy simulation software – both in terms of the technologies that could be modeled and the ability to add new technologies to the software in the future.

Pros and Cons of a Static Benchmark

The static benchmark is easy to understand and communicate. A key advantage to this approach is that it provides the greatest degree of transparency to rating stakeholders. All assumptions used to develop the benchmark could be published and made publicly available. An additional benefit is that a static benchmark allows buildings of a similar type and climate to be compared directly to one another, since the denominator in the rating derivation is exactly the same. Also, design features such as orientation and massing, HVAC system selection, and efficient distribution systems are given credit, since these parameters would not necessarily be included in the static benchmark.

A disadvantage is that buildings with special design requirements (such as the example below) may be penalized. Additionally, this approach may present challenges for mixed use buildings.

Pros and Cons of the Modeled Benchmark

With this approach, the benchmark is modeled and varies for each rated building. The advantage of this approach is that it allows adjustments to the benchmark for design requirements specific to the rated building. For instance, if a building required special air filtration, the benchmark fan power could be adjusted so that the rated building wouldn't be penalized. The rules for when and what type of benchmark adjustments may need to be applied must be very stringent in order to prevent opportunities for gaming and to give proper and consistent credit to assets in rated buildings.

There are several disadvantages to this approach including:

- ***Limited ability to compare similar buildings using the rating.*** The Title 24 ACM defines a baseline for comparison (a "code benchmark") that is custom for every building. Therefore, it would be difficult to use the rating to compare the energy efficiency potential of similar buildings. All buildings designed to exactly meet code are not created equal.
- ***Difficult to credit good architectural design.*** Building design features such as orientation, aspect ratio and massing are not credited in the Title 24 code. However, these are assets that remain a benefit for the life of the building. Some buildings may be constrained by site and other considerations, but the architectural design remains an asset. A new ruleset would need to be created to account for these design features. For example, averaging the energy use predictions of the benchmark rotated in all four cardinal orientations would provide credit to the rated building's orientation.
- ***Difficult to credit high performance features.*** High performance design features such as natural ventilation and well-designed distribution systems are not credited in a compliance rule set. To treat all

Recommendations

The following is recommended to develop benchmarks for the BEARS program:

1) If it is desirable to pursue the performance map approach, its initial scope should be limited to simple building types (<20,000 ft^2, or small office, small retail, warehouse). Owners of small buildings may not have the financial resources or interest in performing energy simulations to maintain an asset rating. Additionally, by limiting the initial scope of the performance map, its development could be focused on populating the database with the most robust set of data possible, even if it is limited to a small number of building types.
2) For larger buildings or more complicated buildings, require the use of an energy simulation. The energy simulation approach could be applied across the full range of building types included in the BEARS program design. Ideally, a consistent approach should be used for all building types and sizes, however, if a mixed approach of the performance map and energy simulation is pursued, testing should be performed to assess whether the chosen approach impacts the calculated BEARS Rating.
3) Utilize a static baseline for asset ratings. The static baseline provides the greatest ability for comparison between buildings of a similar type and therefore will likely be the easiest to understand by the stakeholders.
4) Specify the rating metric to include all energy end-uses, so that a percent improvement in a BEARS score will track more closely with reduction in energy use or energy cost. For example, a supermarket may have energy end-uses unregulated by Title 24, Part 6 (such as refrigeration) that account for 40% of the total energy consumption of the building. An efficient supermarket design may show 50% improvement over Title 24 when accounting for only regulated loads, but this would only be a 30% reduction in total energy use (50% x (1 – 40%)). If the refrigeration loads were not included the asset rating, the building would appear much more efficient and much closer to net zero than if all energy use were included.
5) Base the Benchmark Building on prescriptive efficiency levels in the T24-2008 code. For some building inputs, such as HVAC system type, the benchmark value would have to be fixed by building type, to maintain a static baseline. Using this approach, the classification of building types is critical, because it provides a framework for comparing the asset rating of one building with another. If the benchmark is established to reflect efficiency of a particular code (e.g., T24-2008), the benchmark should *not* be used to infer a percent savings beyond code. Where input values fall outside the scope of prescriptive code requirements, other data sources will be reviewed including COMNET, CEUS, or CBECS.
6) Specify fixed inputs for operational variables as a function only of building type. The building types defined will cover much of the variance in operational characteristics. Additionally, fixed operational variables will allow for equitable comparison of similar building types.